

Ichthyofauna sampled with tadpoles in northeastern Maranhão state, Brazil

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Abstract: The Neotropic region has high fish diversity associated with freshwater habitats. However, for Maranhão state, most publications on the ichthyofauna concentrate on coastal or estuarine ecosystems. In this study, species of fish were sampled in lentic and lotic habitats in Cerrado areas (Cerradão phytophysiology) and in restinga areas (Atlantic Forest phytophysiology) in northeastern Maranhão state between January and July 2010. Thirteen species from 10 families and 6 orders were captured. Species richness was highest for the orders Characiformes and Gymnotiformes. Our results are the first records of the ichthyofauna of coastal drainage areas of northeastern Maranhão state, contributing to the understanding of the biodiversity of the Munim and Parnaíba River basins, and suggest the existence of a community that shares elements with those of the Amazon and Caatinga biomes.

Key words: Cerrado, coastal ecosystems, ecotone, Neotropical ichthyology, species inventory

INTRODUCTION

The Neotropic region supports a high fish diversity associated with freshwater habitats, comprising nearly 4,500 species that can reach 6,000 species (Lowe-McConnell 1999; Reis *et al.* 2003; Lovejoy *et al.* 2006; Graça and Pavanelli 2007; De Araújo *et al.* 2011). However, most publications on the ichthyofauna of Maranhão state, concentrate on coastal or estuarine ecosystems (*e.g.*, Piorski *et al.* 2009; Nunes and Piorski 2011).

Furthermore, habitat destruction, together with the introduction of exotic species, have deeply modified aquatic habitats, affecting the distribution of species (Gomiero and Braga 2008; Aquino *et al.* 2009; Rodrigues *et al.* 2010; De Araújo *et al.* 2011) and consequently, reducing the local fish populations in several South American aquatic systems (Mateus *et al.* 2004; Piorski *et al.* 2008a). This has been also observed in the Cerrado biome (Cerradão Phytophysiology)

and restinga ecosystems (Atlantic Forest phytophysiology), due to growing exploitation of timber, agricultural expansion, fire, and increase in unplanned urban areas (Myers 2000; Machado *et al.* 2004).

In northeastern Maranhão state the situation is no different. The real threats to the biodiversity of this region are the expansion of soybean croplands and *Eucalyptus* fields in the Cerrado areas and housing developments and urbanization in the restinga areas (Silva *et al.* 2008). Therefore, greater knowledge of the biodiversity of this region is particularly important, mainly because the Maranhão state has been considered a broad and diverse biogeographic transition zone (Ab' Saber 1989) with the Amazon Forest in the west, patches of the Caatinga in the east, Cerrado in the center and northeast (IBGE 1984), and coastal ecosystems (restingas and mangroves) in north and northeast.

The aim of this study was to survey fish species sampled together with the tadpole community in lentic and lotic environments in northeastern Maranhão state, Brazil.

MATERIALS AND METHODS

Study area

The study was carried out in nine municipalities in northeast of Maranhão state. The area of study comprises 14,360 km² at altitudes ranging from 19 to 88 m (Figure 1, Table 1). The climate of the region is tropical humid mesothermal with two well-defined seasons: a rainy season from January to June with an average of 94% of the total annual rainfall, and a dry season from July to December with only 6% of rainfall. The annual average is approximately 1,800 mm (IBGE 1984).

The Cerrado biome is considered a hotspot (Klink and Machado 2005) that originally covered nearly 40% of the state of Maranhão (IBGE 1984). The relief is flat and smooth, locally known as Chapada. The Cerradão, is the predominant physiognomy (IBGE 1984), with a very heterogeneous vegetation (Ratter *et al.* 1998) as a result of the

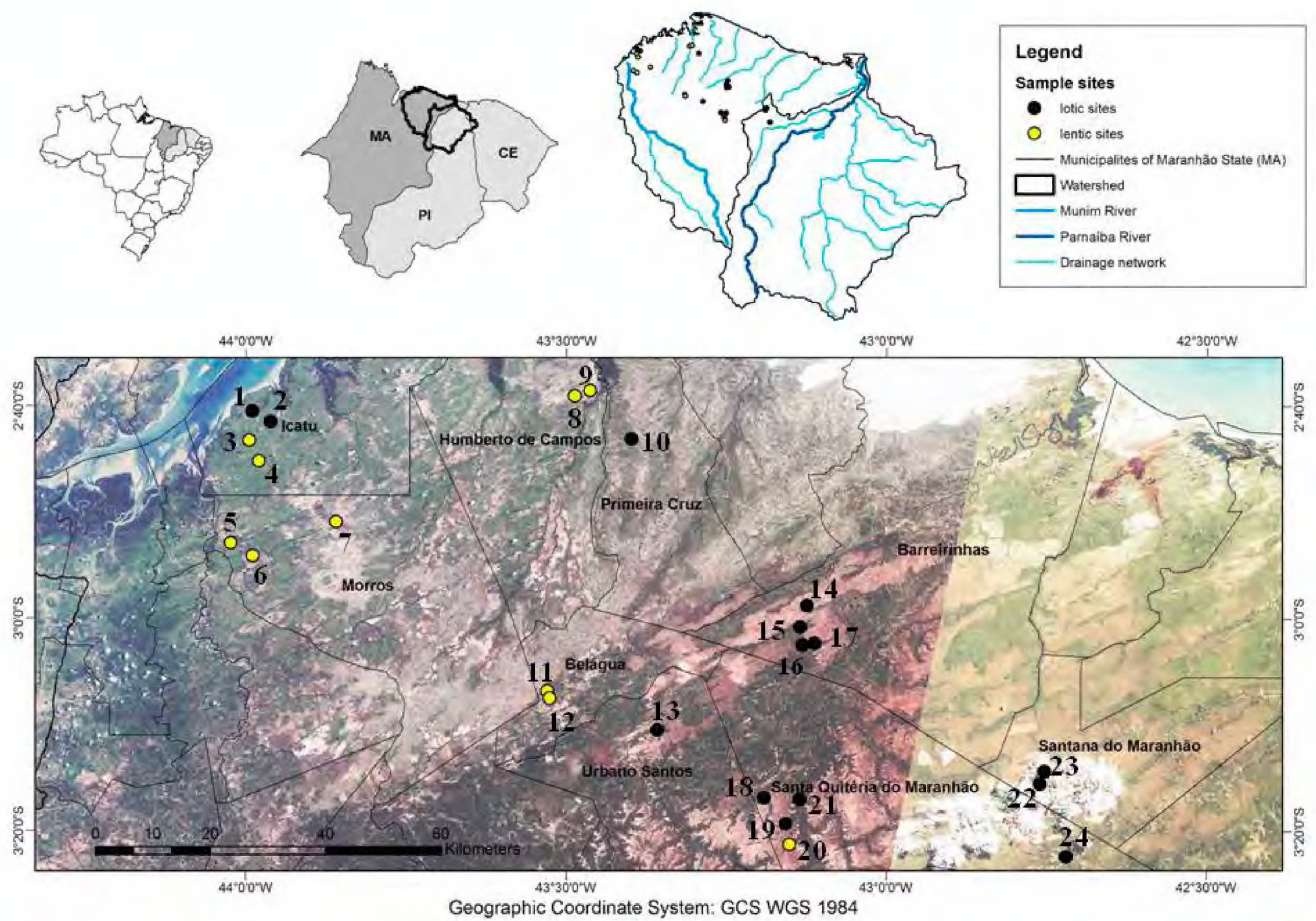


Figure 1. Map of the study region in the northeast of Maranhão state, Brazil. Yellow circles: Lentic environments (small floodplain and pond) and black circles: Lotic environments (buritizais).

contact with other biomes. The restingas (Atlantic Forest phytophysiology), a typical physiognomy of sandy coastal plains (Araujo *et al.* 1998), also considered a hotspot, exhibits a diverse phytophysiology, ranging from coastal herbaceous to dense forests in sandy soil (IBGE 1984; Araújo and Lacerda 1987; Myers 2000). In northeastern Maranhão, restingas ecosystems consist of species typical of the biome as well as those from the rain forest, Caatinga, and Cerrado (MMA/IBAMA 2003).

The collection sites were located in natural watercourses from the Munim and Parnaíba Rivers and independent drainage areas between these two basins (Figure 1).

Ichthyofauna sampling

The qualitative sampling (presence of species) was conducted monthly from January to July 2010 in 24 natural waterways (Figure 1), consisting of 12 sites in Cerrado areas and 12 sites in restinga areas distributed in lentic and/or temporary habitats (two small floodplain and eight ponds) and lotic/permanent habitats (14 buritizais), totaling 24 sites (Figure 1, Figure 2 and Table 1). Sampling of fish followed the method used for tadpole community (Heyer *et al.* 1994). Tadpoles and fishes were collected with a 1-mm mesh sieve up to 1 m from the margins around of the lentic environments (small floodplain and ponds) and in transects of 250 m along the two margins of the lotic environments [gallery forests with crystalline waters and the predominance

Table 1. Geographic coordinates and altitude of the 24 natural waterways sampled in Cerrado and restinga areas in northeastern Maranhão state, Brazil.

Site	Latitude	Longitude	Area	Environment	Altitude (m)
1	43°59'28"W	002°40'29"S	Restinga	Lotic	29
2	43°57'44"W	002°41'29"S	Restinga	Lotic	37
3	43°59'44"W	002°43'14"S	Restinga	Lentic	53
4	43°58'50"W	002°45'11"S	Restinga	Lentic	57
5	44°01'26"W	002°52'57"S	Restinga	Lentic	38
6	43°59'25"W	002°54'07"S	Restinga	Lentic	47
7	43°51'36"W	002°50'56"S	Restinga	Lentic	71
8	43°29'12"W	002°39'03"S	Restinga	Lentic	26
9	43°27'46"W	002°38'32"S	Restinga	Lentic	19
10	43°23'56"W	002°43'06"S	Restinga	Lotic	39
11	43°31'46"W	003°06'51"S	Restinga	Lentic	86
12	43°31'35"W	003°07'30"S	Restinga	Lentic	88
13	43°21'28"W	003°10'31"S	Cerrado	Lotic	65
14	43°07'25"W	002°58'46"S	Cerrado	Lotic	46
15	43°08'05"W	003°00'48"S	Cerrado	Lotic	25
16	43°07'52"W	003°02'29"S	Cerrado	Lotic	39
17	43°06'45"W	003°02'20"S	Cerrado	Lotic	26
18	43°11'27"W	003°16'55"S	Cerrado	Lotic	61
19	43°09'23"W	003°19'21"S	Cerrado	Lotic	62
20	43°09'02"W	003°21'16"S	Cerrado	Lentic	63
21	43°08'07"W	003°17'02"S	Cerrado	Lotic	53
22	42°45'36"W	003°15'32"S	Cerrado	Lotic	69
23	42°45'11"W	003°14'22"S	Cerrado	Lotic	68
24	42°43'08"W	003°22'23"S	Cerrado	Lotic	71

of palm trees (*Mauritia flexuosa* L. [Arecaceae]) with 10–25 m height, which are called “buritizais” (Figure 2) between 10:00 h and 16:00 h. Data sampling was standardized as 1h/day in 24 habitats sampled so that the sampling effort was equivalent among sampled sites. The fishes collected were immediately fixed with 10% formaldehyde and identified with available taxonomic keys and aid of the fourth author. The collected material was deposited in the Coleção de Peixes da Universidade Federal do Maranhão (CPUFMA).

RESULTS

Thirteen species from ten families and six orders were collected (Table 2, Figure 3). Species richness was higher for the order Characiformes (30.76%), followed by Gymnotiformes (23.07%), Cyprinodontiformes (15.38%), Perciformes (15.38%), Siluriformes (15.38%) and Synbranchiformes (7.69%). All species sampled were recorded in the Munim River Basin, and only five species was sampled in Parnaíba. Most species occurred in lotic and lentic habitats, but only the Gymnotiformes and



Figure 2. Examples of some sites sampled in Cerrado and restinga areas in northeastern Maranhão state, Brazil: (A) Slow lotic environment “preserved buritizal” in Cerrado areas located in the municipality of Barreirinhas, MA; (B) Lentic habitat “temporary pond” in restinga areas located in the municipality of Morros, MA; (C) Slow lotic environment “anthropized buritizal” in restinga areas located in the municipality of Primeira Cruz, MA; (D) Lentic habitat “temporary pond” in restinga areas located in the municipality of Humberto de Campos, MA; (E) Lentic habitat “preserved permanent pond” in the Cerrado areas located in the municipality of Santa Quitéria do Maranhão, MA; (F) Lentic habitat “temporary pond” in restinga areas located in the municipality of Morros, MA.

Siluriformes orders were exclusively observed in the lotic habitats sampled.

DISCUSSION

Within the South-American ichthyofauna associated with freshwater habitats, Characiformes and Siluriformes are the most diverse and usually dominant orders (Castro 1999; Lowe-McConnell 1999; Reis et al. 2003; Buckup et al. 2007). In the present study, the Characiformes order was also the most diverse. However, Gymnotiformes was the second in species richness, rather than Siluriformes. This inversion in species richness among orders has been found in stream with high proportion of sandy substrate (Barros et al. 2011), such as the observed in this study.

Of the river basins sampled, only the ichthyofauna of Parnaíba River has been minimally studied, with approximately 75 species of fish recorded (Rosa 2004). However, new records have recently been added for the region, including *Geophagus parnaibae* for Parnaíba River, *Roeboides sazimai* for Parnaíba and Pindaré-Mearim rivers and *Platydoras brachylecis* for Parnaíba, Mearim, and Itapecuru rivers (Staeck and Schindler 2006; Lucena 2007; Piorski et al. 2008b). In this study, of the species collected in streams of the Parnaíba River basin, only *Nannostomus nitidus* is a new record for the state of Maranhão, whereas for the species collected in the Munim River and adjacent coastal basins, where no information was previously

available about the composition of the ichthyofauna, where *Poecilia vivipara*, *Copella arnoldi* and the genus *Rhabdolichops* are also new records for the state.

No previous studies have been conducted with fish from streams that drain the Cerrado and restinga areas in the Maranhão state. However, Piorski et al. (2007) have published a preliminary list of fish from the Cerrado of southern Maranhão. In the present study, the most of the species identified have broad distribution and were already recorded from the Caatinga biome (Rosa 2004). Although *Nannostomus nitidus*, *Poecilia vivipara* and *Copella arnoldi* are three new records for Maranhão state, the *P. vivipara* already was recorded from the Brazilian Northeast ecoregion (Rosa 2004) and *C. arnoldi* from the Amazon basin (Weitzman and Weitzman 2003). Both *Astyanax* sp. and *Rhabdolichops* sp. could not be identified to the species level, and *Rhabdolichops* is recorded for the first time from the coastal drainage of Maranhão state. Altogether, three species and one genus are newly recorded from the state. However, as reported elsewhere for Caatinga areas (Rosa 2004), the systematics of many taxonomic groups from Cerrado and restinga areas in Maranhão state, are not well enough known to allow the identification to species.

Although our results were collected with the tadpole community, these are the first records for the ichthyofauna in streams of the Munim River Basin and coastal drainage areas of northeastern Maranhão state. Our findings indicate

Table 2. Composition of the ichthyofauna sampled in the 24 natural waterways in Cerrado and restinga areas and their environments in northeastern Maranhão state, Brazil. (Watershed: 1= Munim River Basin/coastal rivers/drainage areas and 2= Parnaíba River Basin).

Taxa	Watersheds		Areas		Environments		Vouchers
	1	2	Restinga	Cerrado	Lentic	Lotic	
ORDER CHARACIFORMES							
Family Characidae							
<i>Astyanax</i> sp.	X		X		X		CPUFMA 10858
Family Erythrinidae							
<i>Hoplias malabaricus</i> (Bloch, 1794)	X		X	X	X	X	CPUFMA 10847
Family Lebiasinidae							
<i>Copella arnoldi</i> (Regan, 1912)	X			X		X	CPUFMA 10874
<i>Nannostomus nitidus</i> Weitzman, 1978	X	X	X	X	X	X	CPUFMA 10771
ORDER CYPRINODONTIFORMES							
Family Poeciliidae							
<i>Poecilia vivipara</i> (Bloch & Schneider, 1801)	X		X	X	X	X	CPUFMA 10839
Family Rivulidae							
<i>Rivulus auratus</i> Schreitmüller, 1928	X	X	X	X	X	X	CPUFMA 10785
ORDER GYMNOTIFORMES							
Family Gymnotidae							
<i>Gymnotus carapo</i> (Linnaeus, 1758)	X		X			X	CPUFMA 10873
Family Sternopygidae							
<i>Rhabdolichops</i> sp.	X			X		X	CPUFMA 10868
<i>Sternopygus macrurus</i> (Bloch & Schneider, 1801)	X			X		X	CPUFMA 10872
ORDER PERCIFORMES							
Family Cichlidae							
<i>Apistogramma piauensis</i> Kullander, 1980	X	X	X	X	X	X	CPUFMA 10812
<i>Cichlasoma orientale</i> Kullander, 1983	X	X	X	X	X	X	CPUFMA 10740
ORDER SILURIFORMES							
Family Callichthyidae							
<i>Callichthys callichthys</i> (Linnaeus, 1758)	X	X		X		X	CPUFMA 10808
ORDER SYNBRANCHIFORMES							
Family Synbranchidae							
<i>Synbranchus marmoratus</i> (Bloch, 1795)	X		X	X	X	X	CPUFMA 10865
Total richness	13	5	9	11	8	12	13



Figure 3. Some species of fishes collected with tadpole community in the northeastern Maranhão state, Brazil. (A) *Callichthys callichthys*; (B) *Cichlasoma orientale*; (C) *Poecilia vivipara*; (D) *Gymnotus carapo*; (E) *Hoplias malabaricus*; (F) *Copella arnoldi*; (G) *Rhabdolichops* sp. and (H) *Sternopygus macrurus*.

the existence of a community that shares faunal elements of the Amazon and Caatinga biomes, supporting the hypothesis that the state of Maranhão is a broad and diverse biogeographic transition zone (Ab' Saber 1989) between the Amazon Forest, Caatinga, Cerrado and coastal ecosystems, which has been observed in other studies (Rebêlo *et al.* 2010; Dos Santos *et al.* 2012; Campos *et al.* 2013; Matavelli *et al.* 2013a, 2013b; Matavelli *et al.* 2014a, 2014b).

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